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Title: Electromagnetic Time Reversal (EMTR) For discrete source identification

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Electromagnetic Time Reversal (EMTR)

For discrete source identification

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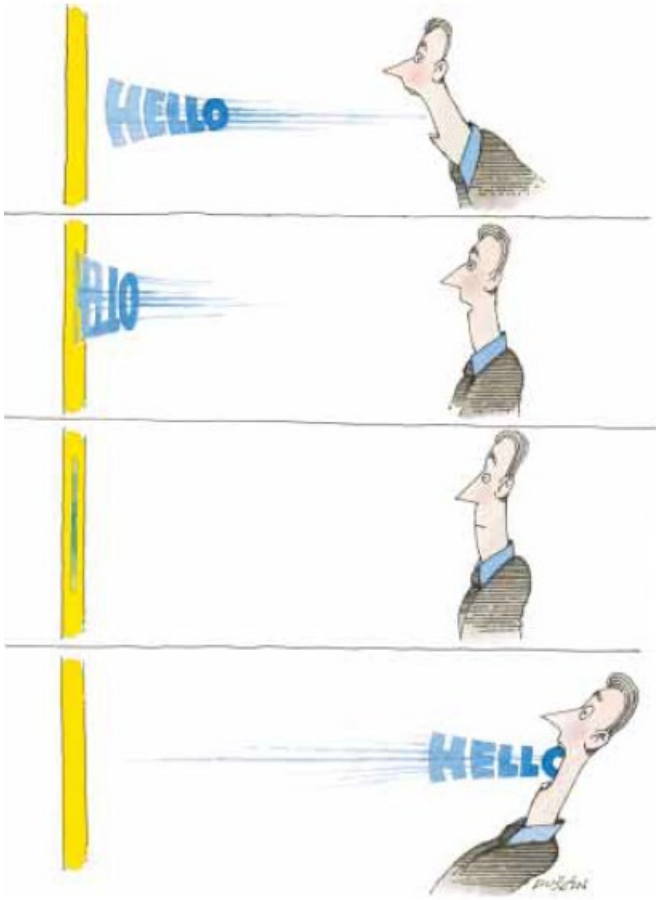
Acoustic TR



Fink, Mathias. "TIME-REVERSED ACOUSTICS." *Scientific American*, vol. 281, no. 5, 1999, pp. 91–97.

What is time reversal

- Signal processing technique that relies on the principle of wave reciprocity
- Applications: Fault detection, wireless power transfer etc.
- Wave equation is time invariant

$$\nabla^2 E - \frac{1}{c^2}\frac{\partial^2 E}{\partial t} = 0$$

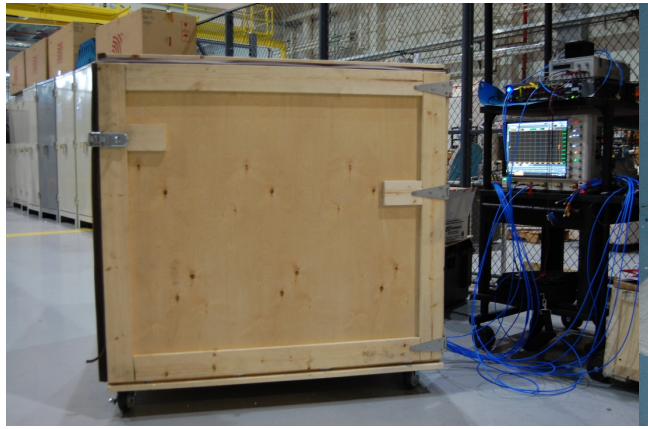
- Both $E(t)$ and $E(-t)$ are solutions due to second order derivatives

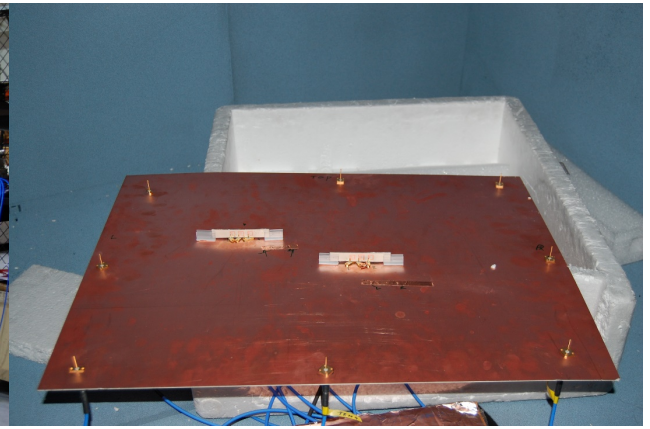
Motivation- EMTR at LANL

- Perform source diagnostics
- Characterize sources/events with subwavelength resolution

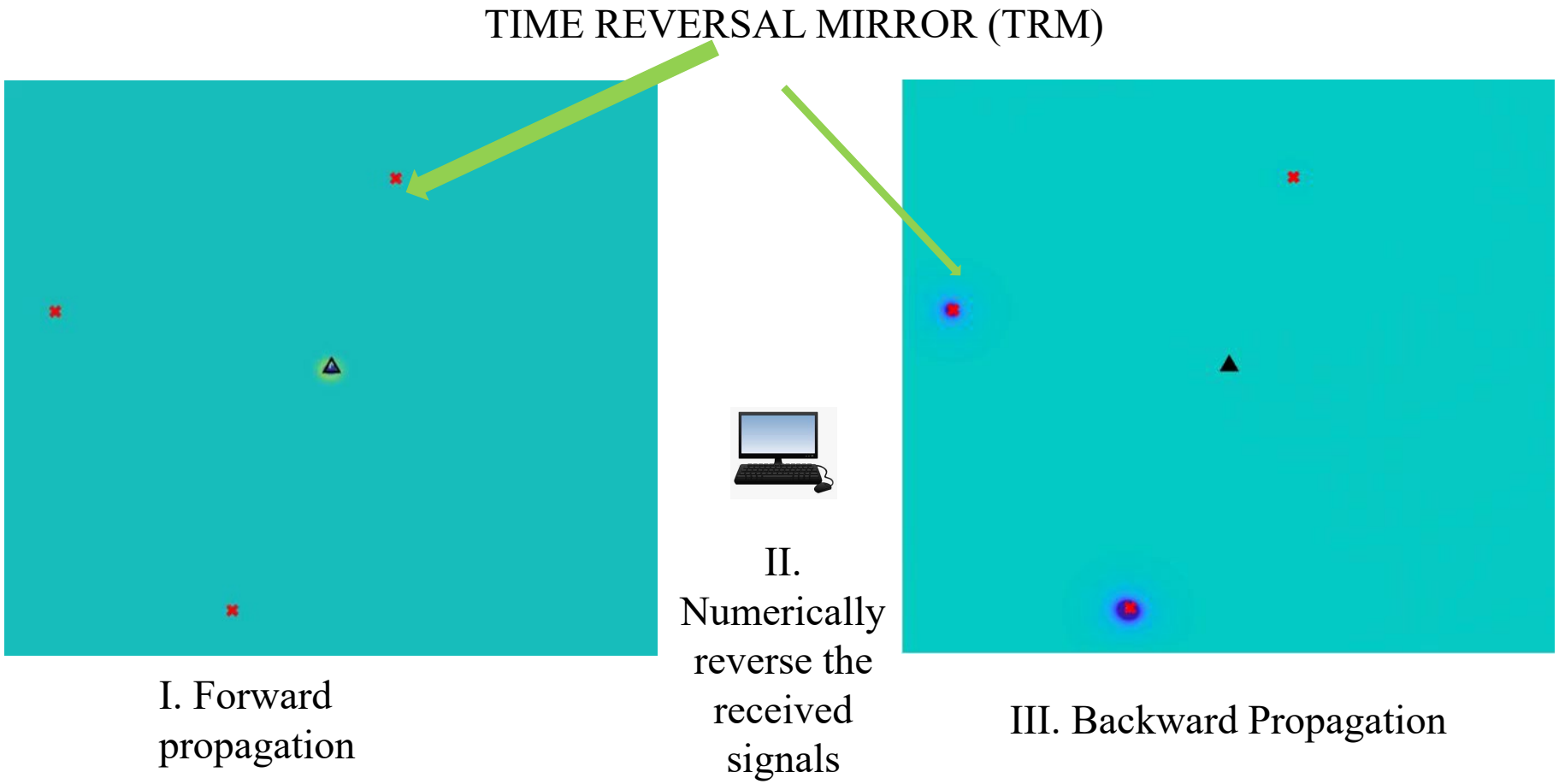
EMTR at LANL

- Successfully demonstrated time reversal using RF waves
- A dedicated test bed, portable anechoic chamber was built for TR experiments
- Multiple sources within the operating bandwidth were characterized
- Numerical simulations and the laboratory measurements agree closely.



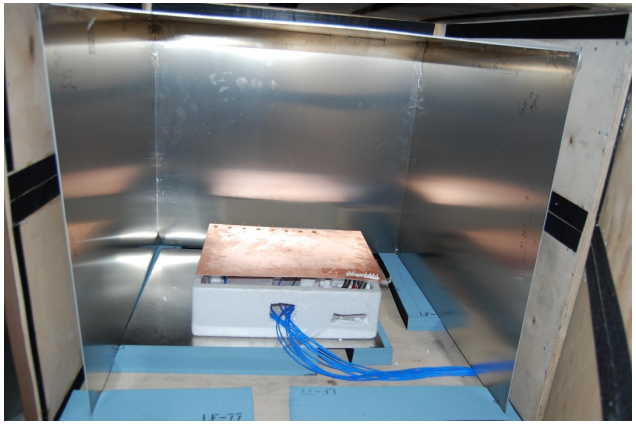


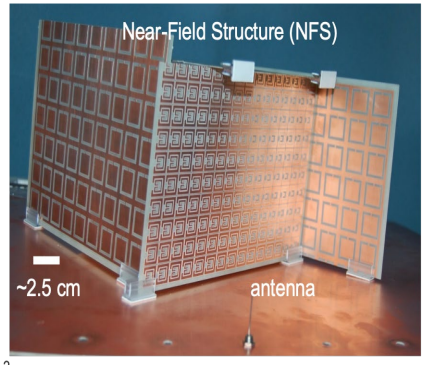
How Time Reversal works

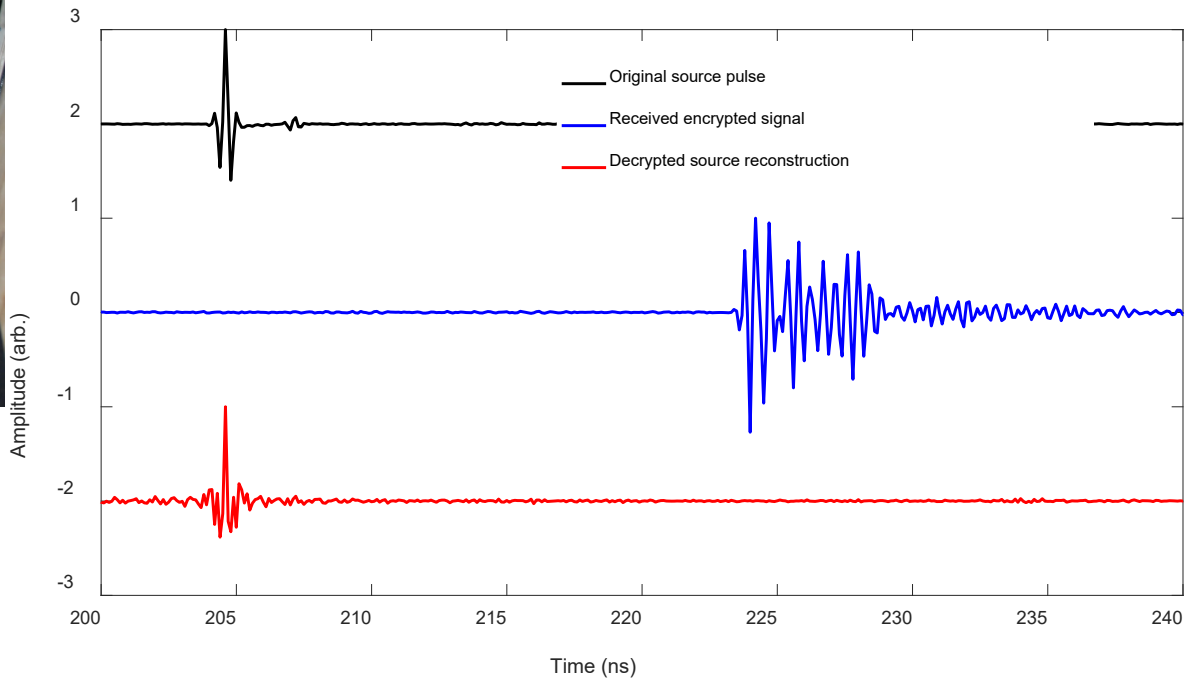


TR is a three step process

TR measurements (1- 4 GHz)





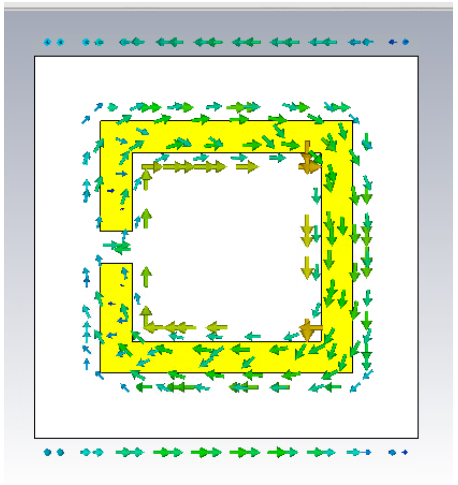


Single source signal reconstruction – only a time measurement.

No spatial discrimination

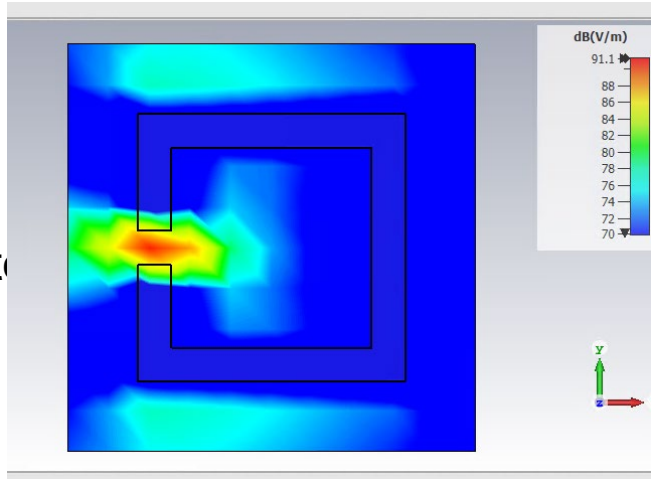
Electromagnetic time reversal with subwavelength resolution

- TR is diffraction limited
- Super resolution shown through loops[1], rods[2] etc. -typically single excitation
- I am using frequency selective resonators to get discrete subwavelength resolution.



Split ring resonators (SRR)

- Near-field to far-field conversion
- Field enhancement at the gap
- Strong frequency selection
- discrete and physically small compared t wavelength

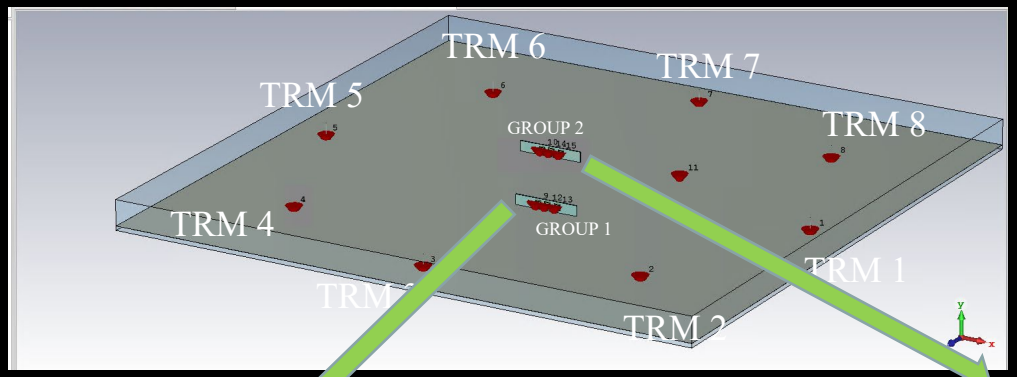


[1] Q. Gao, X. Wang and B. Wang, IEEE Photonics Journal, vol. 10, no. 1, pp. 1-11, Feb. 2018, Art no. 3900111

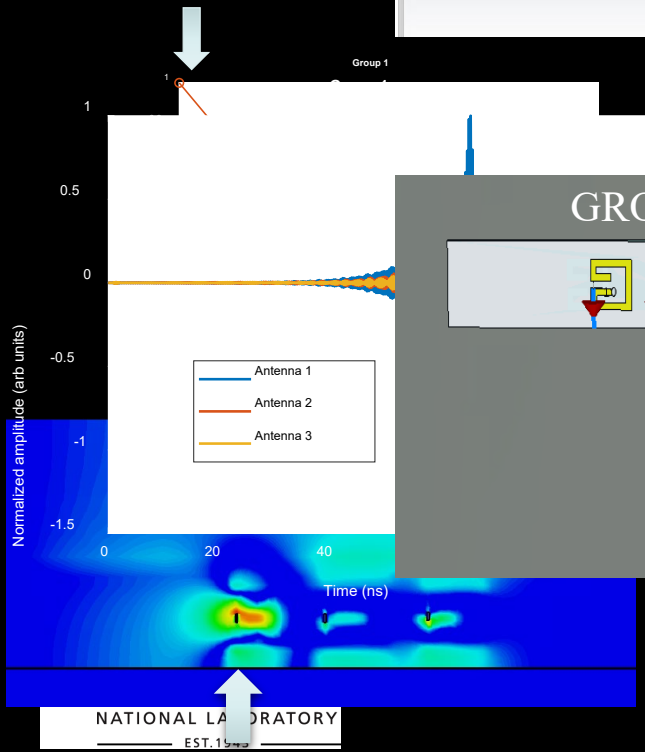
[2] AIP Advances **6**, 055001 (2016);

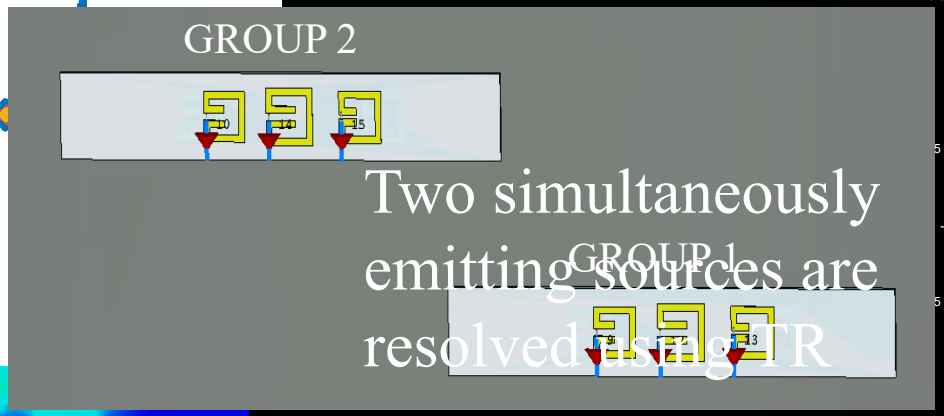
Subwavelength detection using near field resonator/scatterer

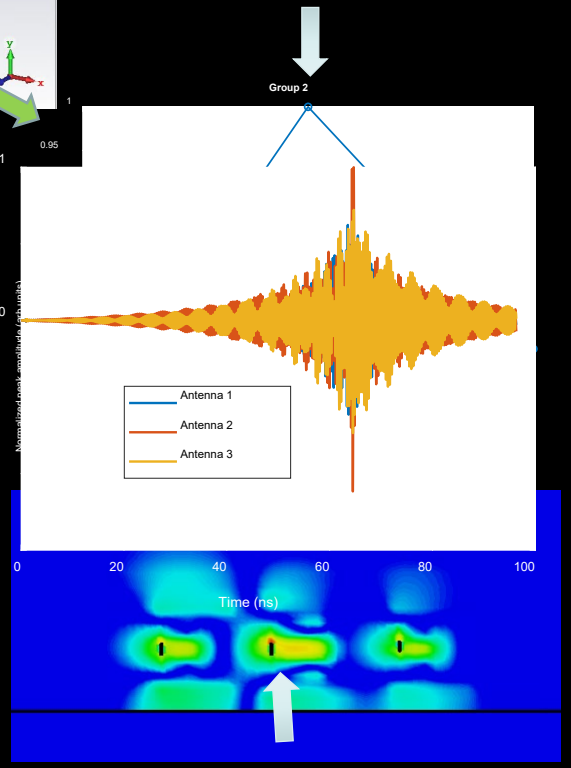
Example: Two simultaneous excitations (Simulation)



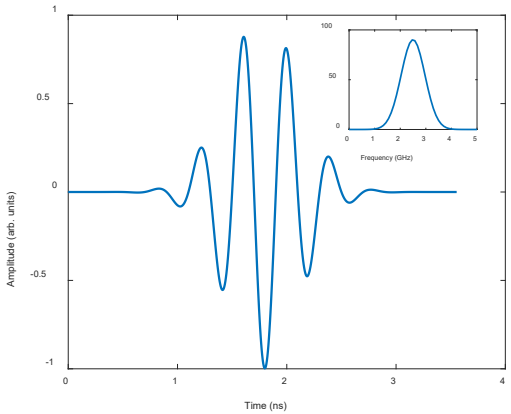
Pulse width: 2 ns
Center frequency: 2.5 GHz

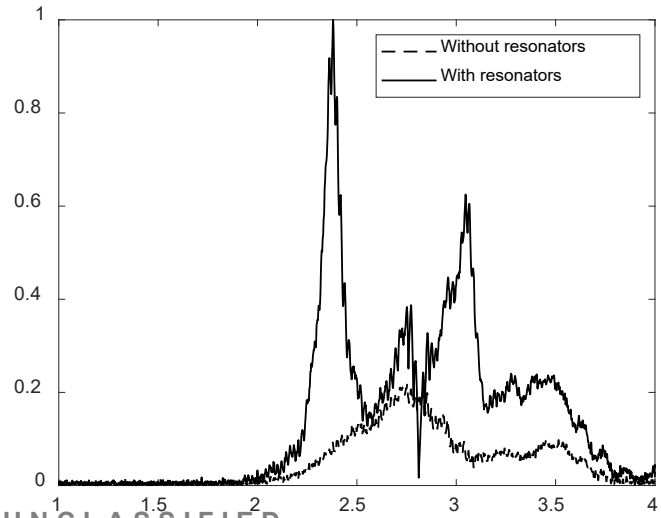






Subwavelength detection using near field resonator/scatterer (measurements)





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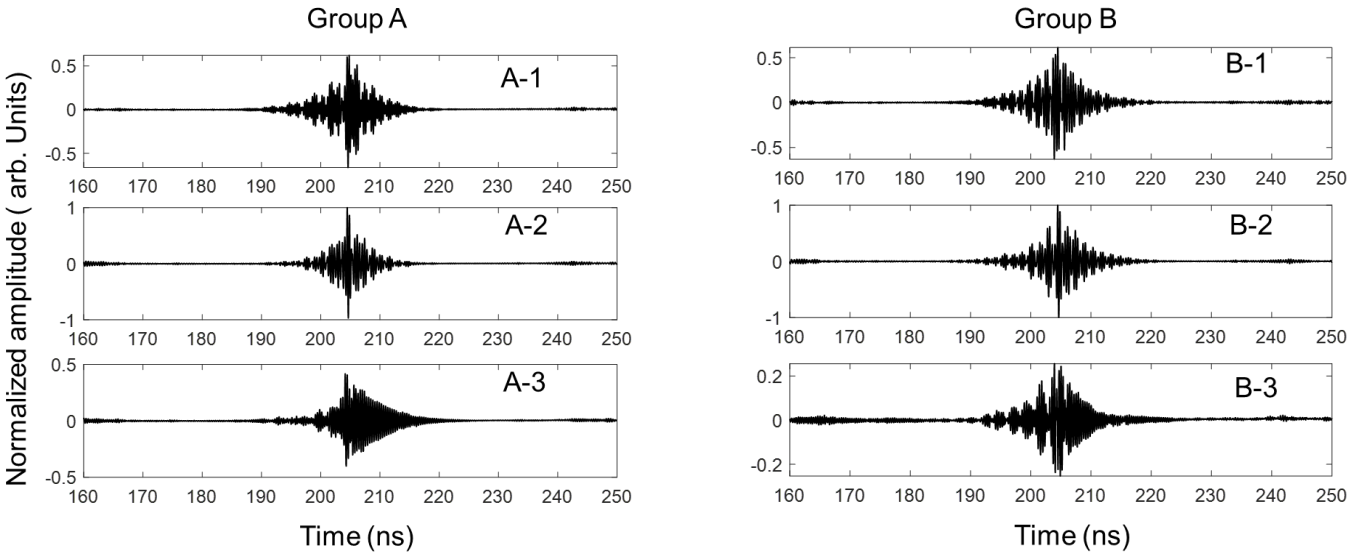
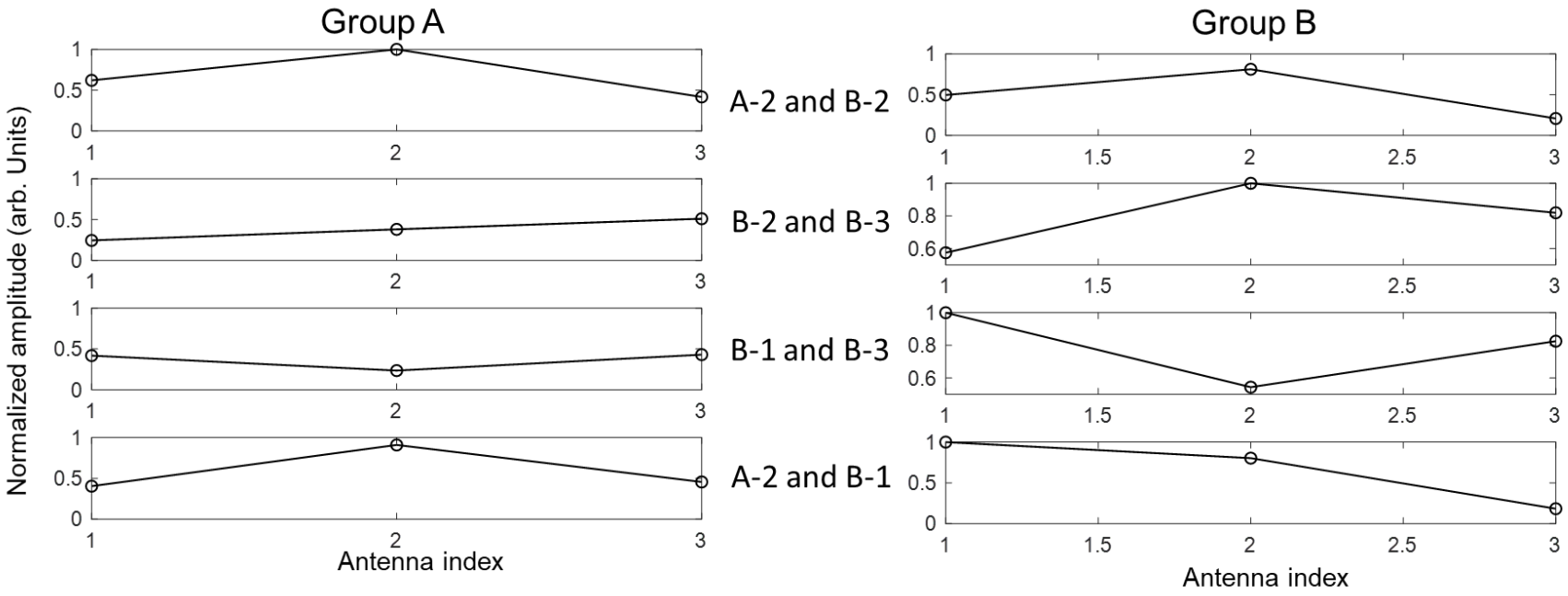

Group A
Group B
Normalized amplitude (arb. Units)
A-1
A-2
A-3
B-1
B-2
B-3
Time (ns)
Time (ns)


Group A
Group B
Normalized amplitude (arb. Units)
A-2 and B-2
B-2 and B-3
B-1 and B-3
A-2 and B-1
Antenna index
Antenna index